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NEW OBSERVATIONS ON THE ORIGIN OF THE GALÁPAGOS ISLANDS, WITH REMARKS ON THE GEOLOGICAL AGE OF THE PACIFIC OCEAN.

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In December, 1890, I wrote a paper,[1] "On the origin of the Galápagos Islands," which was published in the AMERICAN NATURALIST of March and April, 1891, one month before I left for the archipelago. This paper opens with the following remarks: "All islands can be divided into two principal groups: 1. Islands developed from continents or larger bodies of land through isolation or subsidence—*Continental Islands.* 2. Islands not developed from continents, but from submarine portions of the earth—*Oceanic Islands.*

"The flora and fauna of the first group will be more or less *harmonic*—that is to say, the islands will be like satellites of the continent from which they developed, and the whole group comparable to a planetary system. The flora and fauna of the second group will be *disharmonic*—that is to say, it will be composed of a mixture of forms which have been introduced accidentally from other places. It is evident the first group of islands will be affected gradually in the same way; there will be immigrants from other localities besides the original inhabitants.

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[1] Baur, G. "On the Origin of the Galapagos," AMERICAN NATURALIST, March, 1891, p. 217–229; April, 1891, p. 307–326.

"*Continental islands, therefore, may be composed of two floral and faunal elements: first, an original (endogenous) one; and second, a secondary (exogenous) one. Oceanic islands, however, will only contain a secondary (or exogenous) floral and faunal element, they never will show harmonic distribution.*"

By the study of the Galápagos Islands I reached the conclusion that the distribution of the animals was harmonic, and that the theory of the oceanic origin was therefore not correct. This opinion I have sustained in the following papers: 1. Das Variiren der Eidechsen-Gattung Tropidurus auf den Galápagos Inseln., Biol. Centralbl., Vol. X, 1890, p. 475–483. 2. Account of my Trip to the Galápagos Islands, dated Chatham Island, August 28, 1891, AMER. NAT., Vol. XXV, 1891, p. 902–907. 3. Ein Besuch der Galápagos Inseln., Biol. Centralbl., Vol. XII, 1892, p. 221–250, also H. de Varigny. Voyage scientifique aux Isles Galápagos, Revue Scientif., Vol. 50, No. 13, 24 Sept., 1892, p. 391–400. 4. Das Variiren der Eidechsen-Gattung Tropidurus auf den Galápagos Inseln. Festschrift zum siebenzigsten Geburtstage Rudolf Leuckart's, Leipzig, 1892, p. 259–277, 4° (with variation curves). 5. The Differentiation of Species on the Galápagos Islands and the Origin of the Group, Biol. Lect. Marine Biol. Laborat. Wood's Holl., 1894, Boston, 1895, p. 67–78.

In this last paper I gave a table showing the distribution of seven genera on the Galápagos Islands; I also gave a table of the distribution of seven genera of birds on the West Indies. Since the West Indies show harmonic distribution, and since it is proved that they were formed by the splitting up of a continuous land area, the same must be true for the Galápagos.

This paper has been reviewed by Professor F. Ratzel in Leipsic, Professor S. Günther in Munich, and Professor O. Böttger in Frankfort. They all agree with my view. Ratzel says: "Baur concludes from the 'harmonic distribution' of the variations that the Galápagos, like the Antilles, originated by sinking of the sea bottom, and were certainly not formed by single volcanic islands, that they were formerly connected through Cocos Island with Central America." He correctly rejects the hypothesis of the consistency of continents and oceans. (Dr. A. Petermann's Mitteilungen, 1895, Heft 12, p. 184–185.)

Günther[2] remarks: "It is known and generally admitted, that for the solution of the question about the origin of a certain island, or a group of islands, the application of zoogeography is of the highest value. The paper before me shows how important it will be for physiography, if correctly applied. Professor Alexander Agassiz had insisted that the Galápagos Islands never had been in connection with the American continent, but were typical volcanic islands. But, if the single islands are all of marine origin, if they were occupied only later by organisms from the continent, fauna and flora ought to show a pretty variegated aspect, making an impression of a mixture of forms. There would be no reason, why one of the islands, which are all closely placed together, should have been preferred to another one, if really the currents of the air and the sea alone effect the transportation of organic germs.

Baur's detailed examination revealed a totally different picture. He showed that each, or nearly each island has peculiar representatives of certain genera, Tropidurus, birds, etc. This can only be explained by subsidence. The tables given by Baur of the distribution cannot be misunderstood. The Galápagos must be considered as the remains of a Miocene land—connection with the continent, to which belonged probably also the West Indian Archipelago."

Böttger[3] also agrees with me, and finishes his review with the following sentence: "Baur finally reached the conclusion, that the lines of the continents of former geological periods do not agree at all with those of the present continents, the more we go back in geological time the larger are the differences." "With this theoretical exposition he gives us an interesting example, that by biological research deductions can be made for geological problems."

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[2] Günther, S. Naturwissensch. Rundschau, 1895, No. 42, p. 542–543.

[3] Böttger, O. Zoolog. Centralbl., I, No. 15, p. 401–463, Sept. 2, 1895.

Ortmann[4] is of the same opinion, and referring to my papers, he says: "The Galápagos Islands may be considered a classical example of the influence of separation for the formation of species."

Meanwhile Mr. Townsend's[5] paper on the Birds of Cocos Island had appeared, the results of which showed to be very interesting for the question of the origin of the Galápagos.

Dendroica aureola Gould, *Cocornis Agassizi* Townsend, *Nesotriccus ridgwayi* Townsend, and *Coccyzus ferrugineus* Gould were found, the last species having only been known before. *Dendroica aureola* Gould occurs also on the Galápagos, besides it has been recorded on Gorgona Island, on the southeast coast of Columbia, north of Tumaco; at Esmeralda, Ecuador; and Posorja, north of the Island of Puna, in the Gulf of Guayaquil; in western Peru, at Santa Lucia and Tumbez. *Cocornis Agassizi* Townsend is the representative of *Cactornis* (Gray) of the Galápagos, and *Nesotriccus ridgwayi* Townsend very close to *Myiarchus magnisostris*. *Coccyzus ferrugineus* Gould is related to species of Central America and the West Indies. *Cocos Island* is placed between the Galápagos and the Cordillera de Veragua. The 1500-fathom line probably embraces Cocos Island and the Galápagos from the Island of Coiba.

We shall now consider the botanical evidence.

During my visit of the Galápagos (June 10–September 6, 1891) I collected plants on Albemarle, Indefatigable, James, Chatham, Charles, Hood, Gardner, Bindloe, Abingdon, Barrington, Tower and Jervis. These have been determined at the Gray Herbarium of Harvard University by Mr. B. L. Robinson and J. M. Greenman.[6]

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[4] Ortmann, Arnold E. Grundzüge der marinen Thieregographie, Jena, 1896, p. 29; and "On Separation, and its Bearing on Geology and Zoogeography," Amer. Journ. Science, Vol. II, 1896, p. 63-69.

[5] Townsend, C. H. Birds from Cocos and Malpelo Islands, with Notes on the Petrels obtained at Sea. Bull. Mus. Zool., Harvard College, Vol. XXVII, No. 3, Cambridge, July, 1895, p. 121-126.

[6] Robinson, B. L., and J. M. Greenman. Contributions from Gray Herbarium of Harvard University, New Series, No. IX, I. On the Flora of the Galápagos Islands, as shown by the Collections of Dr. G. Baur, Amer. Jour. Science, Vol. L, August 1, 1895, p. 135-149.

From this paper I quote the following: "It is well known not only that the archipelago possesses a peculiar and remarkable vegetation, but that the different islands exhibit in their floras a striking individuality." "While upon some of the smaller islands Dr. Baur collected only a few species, enough material is at hand not merely to confirm strongly the view that almost every island has its peculiar species and varieties, but to show clearly that even plants, which must pass as the same species, often exhibit, when found upon several islands, more or less striking racial differences. These facts, while in other respects noteworthy, derive a special interest from their relation to the probable origin of the flora of the group. Regarding the fauna Dr. Baur has in several recent articles called attention to peculiar harmonic relations existing between the forms of the different islands, and has argued from zoological grounds that the islands must at one time been united, not only with each other but with the mainland near Central America." "This view has been severely criticised by several writers, but no one has attempted to account for the peculiar distribution of differing, yet closely related forms upon the islands, and as the subject is one which merits further attention, it seems worth while to present the botanical data in some detail.

Perhaps no species to be found upon the different islands better illustrates the noteworthy racial divergence in related forms than *Euphorbia viminia* Hook. fil. This species differs markedly in foliage from any other known member of this large genus, and is characteristic of the Galápagos Archipelago. Being essentially a desert plant, it can subsist even upon those islands of the group which are of low altitude and do not attain the upper regions of moister atmosphere. It was first collected by Macrae upon Albemarle, rediscovered by Anderson on Charles, and has now been collected by Dr. Baur on the following islands: Barrington, Chatham, Southern and Eastern Albemarle, James, Jervis, Bindloe, Tower and Abingdon. Even the most cursory inspection of the forms from these different islands discloses marked variation in the contour, size, thickness, rigidity, and color of the leaves, as well as in the length of the intenodes, color of the stem, etc., while more careful examination shows that these are not mere individual differences, due to chance, state of development, or individual environment, but each form appears in general to be restricted to a single island. Some forms, such as those from Abingdon and Tower Islands, differ rather strikingly from the rest, while others present slighter differences, in a few cases too slight, that a series of careful measurements is necessary to demonstrate their existence. But the examination of considerable number of specimens, such as those secured by Dr. Baur, shows that the species as it occurs on each island differs in some characteristics, slight or more considerable from the forms of all or nearly all the other islands, and furthermore, each island appears to have only *one form* of its own.

The question at once presents itself: If this archipelago is composed of islands of elevation, built up from the sea-floor independently by volcanic action, how has such a distribution been effected? If the vegetation has been derived from the mainland by the chance of transportation of seeds, it is quite impossible to believe that each island has received a slightly different form of the same species, and we are forced to the much more natural assumption that racial and varietal divergence has come about after the introduction of the species upon the islands. Now, continuing the supposition that these are islands of elevation, the seeds of *Euphorbia viminea* must have reached them in one of two ways: either each of the nine islands, where we know the species now to occur, must have received its seed directly from the mainland; or, what is much more natural, seed must have reached one or more of the islands, and from there spread to the rest. That the same species should have reached all these islands presupposes a considerable facility of transportation. But as soon as this is granted it is impossible to understand the highly individual development of the forms upon the different islands. For relative or complete isolation seems necessary to account for the racially divergent floras of the islands; and especially for the occurrence of only one form upon each island. It would thus appear necessary, in accounting for the present distribution, to assume that at one time in the remote past the islands were either united, or at least that the channels which separate them were less formidable barriers to seed transportation than at present, so that general distribution of species could have been effected; and that subsequently, as the islands separated, or as the channels through some change of currents, or other cause, became less easily passed, an era of *much* greater isolation of the floras of the different islands came about. The divergence of character of the vegetation would then begin at once, and the otherwise unaccountable existence of a single and peculiar form upon each island would be readily intelligible."

While not prepared to make any positive assertion regarding the probable origin of the islands, the authors fail to see in the hitherto generally accepted theory of elevation any satisfactory explanation for the harmonic yet divergent floras of the different members of the group. Upon Dr. Baur's assumption of a former union between the islands and subsequent separation by subsidence, not only is explanation possible, but the existing flora of the archipelago is just that which would most naturally result from such an origin. A former union of the islands would account at once for the occurrence of identical ancestral species upon the different members of the group, and the subsequent separation give the needed isolation for varietal and racial divergence, while the latter could not have come about if a continental interchange of seeds were taking place from island to island.

Regarding a former land-connection with the continent, which would certainly offer much greater geological difficulties, the botanical evidence is still too vague to merit regard. The affinities of the vegetation of the upper, moister portions of the islands are doubtless, as has been assumed, with the floras of Columbia, Central America, Southern Mexico, and the West Indies, while much of the desert flora of the lower regions has doubtless been derived from the arid regions of Chili and Peru. But, so far as botanical data are concerned, this could have come about either by migration by land or by transportation by oceanic currents, and, as the latter still exist, it seems unnecessary to assume the former. However, on this point, the evidence from the vegetation appears to be still wholly indecisive.

The harmonic relation of the floras of the different islands, which, as we have seen, appears to have such an interesting bearing upon the former possible connection of the islands with each other, is shown not only by *Euphorbia viminea*, but by various other endemic species and groups of species of the same and other genera and orders.

All the Galápageian species of *Euphorbia* for instance, with the exception of *E. amplesicaulis* Hook. fil., form a closely related group, doubtless having a comparatively recent common ancestry; but most of these forms are characteristic of particular islands. The same is eminently true of the different species of *Acalypha*. The *Borreriæ* of the Galápagos Islands also form, for the most part, a close group of very nearly related species, or, perhaps, better varieties of one polymorphous species, all of which have probably diverged from a uniform parent stock after the separation of the insular floras from that of the mainland and from each other. Here, however, we find in some instances the same form upon two or more of the islands, as though transportation of the seed had offered somewhat less difficulties than in the case of *Euphorbia viminea*." The forms of *Euphorbia viminea* Hook. fil. are as follows:

Forma *Albemarlensis* (typica).[7]—Albemarle Island; collected first by Macrae, and again by Dr. Baur, on the southern end of the island in July, and on the eastern side in August, 1891.

Forma *Jacobensis*.—Collected by Dr. Baur near Orchilla Bay, Northern James Island, August, 1891.

Forma *Castellana*.—Collected on Tower Island, by Dr. Baur, September 1891.

Forma *Chathamensis*.—Collected on Chatham Island, lower region, southwest end, by Dr. Baur, June, 1891.

Forma *Carolensis*.—Collected on Charles Island, by Anderson, 1852.

Forma *Barringtonensis*.—Collected on Barrington Island, by Dr. Baur, July, 1891.

Forma *Jervensis*.—Collected on Jervis Island, by Dr. Baur, August, 1891.

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[7] I do not give here the description of these varieties, which may be looked up in the original paper.

Var. *Abingdonensis*.—Collected on Abingdon Island, by Dr. Baur, September, 1891. This form is so well marked as to merit varietal rank.

In *Amarantus sclerantoides* Ands. a racial variation has been noted similar to that in *Euphorbia viminea*. The type of the former was collected on Charles Island by Anderson. Two forms collected by Dr. Baur upon Chatham and Hood Islands differ perceptibly in foliage:

Forma *Chathamensis*.—Collected at Chatham Island, lower region, southwest end, June, 1891.

Forma *Hoodensis*.—Collected on Hood Island, July, 1891.

We shall now see what Mr. W. Botting Hemsley,[8] of the Royal Kew Gardens, has to say, who is a specialist in insular floras.

In 1894 the first part of a splendid series of papers appeared in *Science Progress* under the title, "Insular Floras," in which some remarks about the flora of the Galápagos are made. At the end the following sentence occurs:

"Concerning the origin of the fauna and flora of the Galápagos, Agassiz vigorously attacks and ridicules Baur's theory of subsidence, put forward with so much confidence, and briefly stated thus: '*The Galapagos are continental islands, originated through subsidence;* they all formed at a past period one large island, and this island itself was at a still former period in connection with the American continent.'[9] It will be sufficient to have directed attention to the discussion here. It is worth adding, however, that Baur's article is supplemented by an excellent bibliography."

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[8] Hemsley, W. Botting. Insular Floras. Science Progress, Vol. I, No. 5, July, 1894, p. 400–401.

[9] These words occur in my paper on the "Origin of the Galápagos Islands," April, 1891, p. 307, published before my departure. The sentence which expresses my theory is preceded by the following words: "I started with the sentence that continental islands must have a harmonic flora and fauna. In the Galápagos we found absolute harmony; my conclusion, therefore, is," etc. I have replied to the criticisms made by Prof. Agassiz in his "General Sketch of the Expedition of the Albatross," from February to May, 1891, (Bull. Mus. Comp. Zool., Harvard Col., Vol. XXIII, No. 1, Cambridge, Feb., 1892) in Science, Vol. XIX, No. 477, March 25, 1892, p. 176. From this I quote the following: "Professor Agassiz has completely overlooked the main point of my argument. This I considered the harmony in the distribution of fauna and flora, as will be seen by referring to my paper. I tried to show that this harmony was absolutely unexplainable by the theory of elevation. After this was done, I examined whether our present knowledge of the soundings showed any serious obstacle to

On October 24, 1895, Hemsley[10] published a review of Robinson's and Greenman's Flora of the Galápagos Islands.

" Dr. G. Baur's theory of the origin of the Galápagos Islands is too well known to need explanation here; yet, it may be briefly designated the theory of subsidence. He argues that the islands were formerly connected with each other, and at an earlier period with the American continent. It is also almost needless to say that this theory has met with an exceedingly hostile recognition. The publication of an account of the botanical collections (Robinson and Greenman) affords an opportunity of examining this theory from a botanical standpoint. For the purposes of the 'Botany' of the *Challenger* Expedition, and ever since that publication of this work, I have collected all the data coming under my notice bearing on the dispersal of plants to considerable distances by wind, water, birds or other creatures, excepting human. The evidence thus collected sufficiently accounts for the vegetation of low coral islands, and the littoral vegetation of widely separated countries; but it in no way helps to explain the vegetation of the enormously distant islands of the Anarctic seas, for example, or that of the islands of the Galápagos group, to give another instance.

" But these are not parallel cases; they are the two extremes in the amount of differentiation in connection with isolation.

" The biological phenomena of the Galápagos Islands left a deeper impression, probably, on the mind of Darwin than those of any other part of the world he visited, and doubtless had

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the theory of subsidence, and I found that it did not. *Professor Agassiz did not refer with one word to this harmony of distribution, which formed the basis of my whole ideas.* When Professor Agassiz, or any one else, is able to explain this by the elevation theory, I shall be the first one to adopt it. But, until this has been done, I believe in subsidence. The paper to which Professor Agassiz refers was written before my visit to the islands. My investigations have only more convinced me of the insufficiency of the elevation theory."

[10] Hemsley, W. Botting. The Flora of the Galápagos Islands. Nature, Vol. 52, No. 1356, October 24, 1895, p. 623.

much to do with his later conception of the origin of species. The fact on which he laid special stress was that the genera, to a very great extent, were the same as in all the islands, and the species different in each island. Dr. Baur's much more extensive zoological and botanical collections and observations confirm and emphasize the correctness of the view of his illustrious predecessor of fifty years ago. Darwin especially refers to the existence of different species or races of tortoises and mocking-thrushes [*Nesomimus*] in many of the islands; and Baur's examination of the lizards of the genus *Tropidurus*, from twelve of the islands, reveals the same condition of things. The botanists bring forward *Euplorbia viminea* in illustration of this phenomenon. This species was described by Sir Joseph Hooker from a single specimen collected by Macrae in Albemarle Island, and the author remarks that he "knew of no species with which to compare this highly curious one." Dr. Baur collected it extensively in eight of the islands, and the specimens from almost every one of them [7] exhibit distinct racial characteristics. *Acalaphe*, a genus of the same natural order, presents somewhat more pronounced variation in the different islands, which some botanists regard as of specific value; other botanists, as of varietal value only. Whatever status we give these forms, the flora as a whole is a most instructive and convincing illustration of evolution.

"A remarkable peculiarity of the Galápagos flora as an insular flora is the almost total absence of endemic genera, for the two or three genera of the Compositæ restricted to the islands are so closely allied to the American genera as hardly to count as distinct. Indeed, the whole flora is so thoroughly American that, apart from geological difficulties, it might be regarded as a differentiated remnant thereof, rather than derived therefrom, after the supposed elevation of the islands. Analogous conditions and phenomena are repeated in the deep valleys of the great mountain chains of northern India and western China, where, in neighboring valleys, the genera are to a great extent the same and the species different.

"Looking at the composition of the Galápagos flora, especially with an eye to the probabilities of the transport of the seeds of its constituents, combined with present conditions, Dr. Baur's theory seems deserving of more serious consideration than it has hitherto received. My slender knowledge of geology alone prevents me from taking up a more decided position."

The last communication of Hemsley[11] appeared in the June number of *Sciencc Progress*, 1896. He writes: "When reviewing the newer literature relating to the flora of the Galápagos Islands I found little to add to what had been done by Darwin, Hooker and Anderson; merely mentioning the visit of the United States ship *Albatross*, and Dr. Baur's theory of the origin of the fauna and flora. Since then an account of Dr. Baur's botanical collections has been published, and the substance has also appeared in an English journal, and Dr. Baur himself has written and lectured in defense of his theory of the origin of this group of islands. As previously stated, he contends that the evidence points to the present condition being the result of subsidence, that the islands were formerly connected with each other, and at a still earlier period with continental America. Although this theory has been derided, I think the biological data strongly favor its correctness; and the soundings given in the map accompanying Agassiz's report of the *Albatross* expedition show a relatively shallow area in which the Galápagos Islands are situated, and which extends eastward to the mainland of Veragua. Probably the segregation would be greatly anterior to the segregation of the West Indian Islands."

It is seen that the subsidence theory has won very extensive ground, in fact, there are only very few opponents left which in the future might be converted. Besides Agassiz, whom I have mentioned before, Stearns, Dall and Wolff. Dr. Stearns[12] had only seen my paper published in the AMERICAN NATURALIST (March, April, 1891), before my visit to the Galápagos. He believes in the elevation theory and the accidental importation of the fauna and flora by currents.

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[11] Hemsley, W. Botting. Insular Floras. Part VI. Science Progress, Vol. V, No. 28, June, 1896, p. 298–302.

[12] Stearns, Robert E. C., Ph.D. Report on the Mollusk-Fauna of the Galápagos Islands, with Descriptions of New Species. Proc. U. S. Nat. Mus., Vol. XVI, p. 353–450, Pl. LI–LII, Washington, 1893.

W. H. Dall,[13] who has written the most extensive work on the landshells of the Galapagos Islands, also adopts the accidental introduction of the fauna. He says, p. 403: "Omitting the *Auriculidæ* and *Siphonariidæ*, we have, as supposed, peculiar forms in each group of islands: twenty-one characteristic of the southeastern, fourteen from the central, and one from the northeastern group of islands, which agree well with the hypothesis that the species originated with forms brought by winds and currents which impinge first on the southeastern group.

On the other hand, it is certain that the southeastern islands are much better known than either of the other groups, and that the area and fertility of the central group are such that there is every reason to suppose many more forms remain to be discovered there, perhaps, including some of those so far known only from the southeastern islands. Prudence strongly urges, that we know too little of the mollusk fauna yet to intelligibly discuss its inter-island distribution."

If the seeds of the different forms of *Euphorbia viminea* Hook. fil. are not blown or floated from one island to the other, as we have seen above, I cannot imagine that the landshells have been transported from island to island, or even from the American continent. Why ought these animals form an exception from the other ones?

Dr. Th. Wolf[14] does not agree at all with the subsidence theory. He says: "Every geologist will stand up against Dr. Baur's hypothesis, until he shall have proved that it is absolutely indispensable for the explanation of the organic creation (organische Schōpfung) of the islands. The answering of the question: How have the present species of animals and plants been developed from the immigrated (or, according to Baur, the remaining) South American[15] species? is very difficult. Here opens, of course, an enormous field for speculation, and, as long as the opinions on the fundamental causes of the origin of species are so different, as to-day, the attempted explanations will be different. *Non nostrum inter vos tantas componere lites.*"

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[13] Dall, William Heally. Insular Landshell Faunas, Especially as Illustrated by the Data Obtained by Dr. G. Baur in the Galápagos Islands. Introductory. Proc. Acad. Nat. Sci.. Philadelphia, August, 1896, p. 395–459, Pl. XV–XVII.

[14] Wolf, Dr. Th. Die Galápagos-Inseln. Verhandl. Ges. Erdkunde. Berlin, Bd. XXII, 1895, No. 4 u. 5. Berlin, 1895, p. 246–265, Taf. 3.

[15] I never said that they came from South America.

Mr. Ridgway[16] does not reach a definite conclusion about the origin of the Galápagos, but he says: "If the apparent relationships of the fauna have any bearing on the question, I believe Dr. Baur's theory to be at least worthy of serious consideration."

In regard to the question of relationship of the six peculiar genera of the Galápagos, Ridgway reaches the following conclusion. Only two (*Nesomimus* and *Nesopelia*) are of evident American relationship. The remaining 3 [4] have so obvious a leaning toward certain Hawaiian Dicæidine forms that the possibility of a former land connection, either continuous or by means of intermediate islands as 'stepping stones,' becomes a factor in the problem. It may be that the resemblance of *Cocornis*, '*Cactornis*,' and *Camarhynchus*, to the above-mentioned Hawaiian forms (*Lorioides*, *Telespiza* and *Psittirostra*) is merely a superficial one, and not indicative of real relationship. I do not by any means claim, on the strength of such evidence, a common origin for them, but merely present the facts as 'food for reflection.' *Certhidea* is also compared with Hawaiian genus *Oreomyza*, of the chiefly Polynesian family *Dicæidæ*.

Since there is no relation whatever of the Galápagos fauna and flora as a whole to fauna and flora of the Hawaiian Islands, the similarities between these birds are certainly only superficial. A former connection between the Galápagos and the Hawaiian Islands is entirely out of the question, these two archipelagos are 7350 miles distant from each other, there is not a single island placed between them, and the intervening sea is 4000 meters deep.

For the opponents of the subsidence theory I give now a few striking examples of continental islands.

The *Solomon Islands* are connected by the 2000 m. line with New Guinea and the New Hebrides. The Solomon Islands possess 12 species of Amphibia.[17]

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[16] Ridgway, Robert. Birds of the Galápagos Archipelago. Proc. U. S. Nat. Mus., Vol. XIX, p. 465–467. Washington, 1896 [published April 1, 1897].

[17] Boulenger, G. A. On the Reptiles and Batrachians of the Solomon Islands. Trans. Zool. Soc. London, Vol. XII, part I, April, 1886, p. 47–62, pl. VIII–XIII. Second Contribution to the Herpetology of the Solomon Islands. Proc. Zool. Soc., 1887, II, p. 333–338.

The family *Ceratobatrachidæ* Boulenger with *Ceratobatrachus günteri* Boul. is only found there. The other species are:

Ranidæ.

Rana bufoniformis Boul., nearest to *Rana kuhlii* (Schleg.) Dum. and Bibr. from the Indian Archipelago (Java, Borneo, Celebes), S. China.

Rana guppyi Boul., as large as the bull-frog, nearest to *Rana gruniens* Daud., Amboyna and Java.

Rana opisthodon Boul., near *R. guppyi* Boul. and *R. gruniens* Daud. This form develops in the egg without metamorphosis, like *Hylodes martinicensis* Tschudi.

Rana krefftii Boul., related to *R. erytraea* Schleg., from the East Indian Archipelago and the Malayan Peninsula.

Cornufer dorsalis A. Dum., also found on the Fiji Islands.

Cornufer guppyi Boul., related to *C. dorsalis* A. Dum.

Cornufer solomonis Boul., near *C. corrugatus* A. Dum., from New Guinea and Duke of York I.

Batrachylodes vertebralis Boul., only known from the Solomon Islands.

Hylidæ.

Hyla macropus Boul.

Hyla thesaurensis Peters.

Hyla lutea Boul.

The presence of this peculiar Batrachian fauna on the Solomon Islands would be sufficient proof for their continental origin, but this is also shown by the geology of the group.[18] There have been found granitoid porphyrites, serpentines and old sedimentary rocks represented by quartzites and crystalline schists.

New Caledonia is surrounded by a deep sea of 2000–4000 m., but it is a typical continental island, as is shown by the geology.[19] There are extensive primitive schists, gneiss and other crystalline rocks, and the Triassic and Cretaceous cover extensive areas.

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[18] Guppy, H. B. The Solomon Islands, their Geology, General Features and Suitability for Colonization. London, 1887.

[19] Bernard, Augustin. L'Archipel de la Nouvelle-Calédonie. Paris. Hachette et Cie, 1895, p. XXIV, 458. Deux cartes et beaucoup de figures. This is a very important work, not only for the geology of New Caledonia, but for the whole western region of the Pacific Ocean.

The *Fiji Islands* are even more isolated, being surrounded by a sea of 2000–4000 m. South of this group the soundings show 4000–6000 m.,and east from the Tonga Islands even 6000–8000 m. But on the Fiji Islands we find three species of frogs: *Cornufer dorsalis* A. Dum., only known from the Solomon Islands, besides two peculiar species, *Cornufer vitianus* A. Dum. and *C. unilineatus* Peters.

The genus *Cornufer* Tschudi shows the following interesting distribution (Boulenger: Catalogue Batrachia Salientia s. Ecaudata, London, 1887, p. 107–111).

1. *Cornufer unicolor* Tschudi. New Guinea.
2. *Cornufer guentheri* Boul. Philippines.
3. *Cornufer mayeri* Günth. Philippines.
4. *Cornufer jagorii* Peters. Samar Island.
5. *Cornufer corrugatus* A. Dum. Philippines, New Guinea, Duke of York Island.
6. *Cornufer punctatus* Peters & Doria. New Guinea.
7. *Cornufer guppyi* Boul. Solomon Islands.
8. *Cornufur solomonis* Boul. Solomon Islands.
9. *Cornufer dorsalis* A. Dum. Solomon and Fiji Islands.
10. *Cornufer vitianus* A. Dum. Fiji Islands.
11. *Cornufer unilineatus* Peters. Great Viti Island (Fiji I.).

A still more peculiar fact is the presence of a very large Iguanoid Lizard *Brachylophus fasciatus* (Brongn.), also found on the Friendly Islands. The nearest relatives of *Brachylophus* Cuv. are *Conolophus* Fitz. and *Amblyrhynchus* Bell from the Galapagos; *Iguana* Laür., Tropical America; *Metopoceras* Wagler, San Domingo; *Cyclura* Harlan,West Indies (Cuba, Jamaica, Bahamas); and *Ctenosaura* Wiegm., Central America.

Of the 50 genera of *Iguanidæ* 47, with over 300 species, are American; two genera, *Chalarodon* Peters, with a single species, and *Hoplurus* Cuv., with three species, are found in Madagascar. This is certainly a very interesting case of distribution.

The genus *Enygrus* Wagler, a snake of the family *Boidæ* (Subfamily *Boinæ*) is represented by four species, which show the following distribution:[20]

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[20] Boulenger, George Albert. Catalogue of the Snakes in the British Museum. (Nat. Hist.) Vol. I, p. 104–109, 1893.

1. *Enygrus bibronii* Hombr. & Jacq. Fiji, Friendly or Tonga and Solomon Islands (San Cristoval).

2. *Enygrus australis* Montrouzier. New Britain, Solomon Islands, New Hebrides, Loyality Islands, Samoa.

3. *Enygrus carinatus* Schneid. Pelew Islands, Ternate, Ceram, Amboyna, Timor Laut, Misol, New Guinea, Louisiade Archipelago, Duke of York Island, Solomon Islands.

4. *Enygrus asper* Günth. Misol, Salavatti, New Guinea, and Duke of York Island.

The presence of *Cornufer*, *Brachylophus* and *Enygrus* can only be explained by the continental origin of the Fiji Islands. Here, also, the geological proof has been given.[21]

In 1862 and 1865 the Fiji Islands were visited by Graeffe, and from 1876–78 by Th. Kleinschmidt, sent there by the Museum Godeffroy in Hamburg. Gräffe collected rocks on Viti Levu and on some small islands belonging to the Exploring Islands; Kleinschmidt on Viti Levu, Kandavu, Ono, Vatu Lele and Ovalau. The material has been worked up by Arthur Wichmann.[22]

The most important result reached by the examination of the Kleinschmidt-collection consists in the demonstration of the existence on the Fiji Islands (Viti Levu) of old crystalline massive rocks and crystalline schists in considerable extension. The following rocks belonging to the chrystalline schists have been found: Amphibolites, Eurites, Quartz-mika-schists, granular Limestone. Of the most important older massive rocks occur Granite, Quartz Porphyry, Diorite, Gabbro, Diabase, Foyaite, and a Sandstone similar to Itacolumit. These rocks have been found partially *in situ*, partially they have been picked up from the beds of different brooks and rivers. No trace of paleozoic and mesozoic strata have been discovered. The youngest massive rocks are represented only by Andesites and Basalts, the former very much more developed. Their tuffs and conglomerates are often fossiliferous, and form the superficial cover. These fossils are of Tertiary age, and certainly not older than Miocene. Of minerals: gold, copper, quartz, pyrite, hæmatite and others were found. All the other islands visited by Kleinschmidt, Kandavu, Ovalau, Ono, Vatu Lele and the Munia, Kanathia, Vanuna-Bulavu of the Exploring Islands, on which Gräffe collected, consist nearly entirely of Andesites and Basalts and their tuffs. In some, for instance, Ono, Vatu Lele, coral-rocks and silicified corals occur.

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[21] I have reached the conclusion about the continental origin of the Fiji Islands before I knew of the geological proof by Wichmann. This paper I saw for the first time in June of this year in the Crerar Library.

[22] Wichmann, Arthur. Ein Beitrag zür Petrographie des Viti-Archipels. Mineralog. und Petragraph. Mittheilungen: herausgeg. von G. Tschermak. (Neue Folge) 5. Band Wien, 1883, p. 1–60.

If we compare the results found on the Fiji Islands with the geological conditions of other islands of the Pacific Ocean, we partly observe very surprising similarity. A very short time ago it was considered as certain, and generally accepted, that all islands of the Pacific Ocean originated through volcanic activity. As exceptions were named New Zealand and New Caledonia. The investigations of the last years have brought forward more light about several of these conditions. Drasche, in 1879 (Neues Jahrb. Min. Geol., 1879, p. 265), stated that only those groups of islands placed eastwards from a line extending from Kamtschatka over Japan, the Philippines, New Guinea, New Caledonia, New Zealand, Auckland, Macquarie to Arctic Victoria, are either coral islands, or consist of young volcanic rocks.

Outside of this line there are, besides the Fiji Islands, some other groups. From the *Pelew Islands* Wichmann described large blocks of a very coarse-grained hornblende-granite and diabase, found at the seashore and at elevations of 400 m. [Journal des Museum Godeffroy, 1875, VIII, p. 126.] Marcou has reported granite and gneiss from the *Marquesas Islands*, and Eichwald[23] has shown that the Aleutian Islands contain Cretaceous strata.

Wichmann makes the following remarks at the end of his paper: "No older massive rocks or sedimentary strata are known from the other "volcanic" groups of islands of the Pacific Ocean, and on some of these, for example, the Galápapos or Sandwich Islands, it seems really to be made out that they have been built up by younger and recent volcanic masses. There is a possibility, and even probability, however, that older formations served as fundament, the examination of which is prevented by the extensive covering."

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[23] Eichwald, E. Geognostisch-palæntologische Bemerkungen über die Halbinsel Magischlak und die Aleutischen Inseln. St. Petersburg, 1871.

From the facts mentioned, it follows that these islands in the Pacific, which, so far as known, are merely of volcanic origin, are not of much significance. Besides, various extensive regions have been terra firma during long periods. On the groups of islands which extend from the Philippines to the Fiji Islands, all marine sediments are missing up to the upper Cretaceous (New Britain), on the others even up to the Miocene. It is remarkable that the northern islands (Japan) and the southern (New Zealand) show the different formations very much more developed. A complete representation of the strata is not found in a single group of islands, therefore, we can suppose that they, together with portions of the ocean, formerly represented continental masses. Thus, it becomes probable, that the Pacific Ocean cannot be considered of great age, that it received approximately its present form only during the time of the younger Tertiary (Wichmann).

From the peculiar fauna of the Fiji Islands we reached the conclusion that they must be of continental origin. The correctness of this conclusion follows from Wichmann's petrographical studies of the rocks.[24]

For the Galápagos Islands the correct geological proof cannot be given, but the harmonic distribution of fauna and flora can only be explained by their continental origin. The connection must have been with Central America and the West Indies over Cocos Island. There are no geological difficulties, since we know that the Fiji Islands, which are surrounded by much deeper sea, are continental.

It is evident that the theory of the consistency of continents and oceans since palæozoic times, or ever before, must be abandoned completely. Edward Suess,[25] in his masterly work, "Das Antlitz der Erde," has fully demonstrated the fallacy of this theory. If Dr. Alfred Russel Wallace[26] would have studied this work and those of W. T. Blanford, O. Feistmantel, W. Waagen, Melchior Neumayer, and others, he could not have accepted the theory of the permanence of the great oceanic basins, which he still defends in 1892, quoting the late Prof. Dana, Mr. Darwin, Sir Archibald Geikie, Dr. John Murray, Rev. O. Fisher and himself as authorities, not mentioning any of the names just given.

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[24] Only by this theory many very peculiar cases of distribution in the Pacific Region and the presence of Pacific and Asiatic forms on the coast of America can be explained.

[25] Suess, Eduard. Das Antlitz der Erde. 2. Bände Wien, 1885–88. Band I. Zweite unveränderte Auflage Wien, 1892.

We know now that there existed a *Lemuria* or *Gondwana Land*, an *Antarctic Continent*,[27] which extended to India, South Africa, South America, and that the Pacific Ocean has not been an ocean since palæozoic or archæan times, but is probably even of recent (Tertiary) date.

In order to reach correct conclusions about these often very complicated questions, it is necessary to use all the data offered by modern geographical and palæontological distribution of fauna and of flora geology.

(*To be Continued.*)

ON THE AFFINITIES OF TARSIUS: A CONTRIBUTION TO THE PHYLOGENY OF THE PRIMATES.

By Charles Earle.

(*Continued from page 575.*)

The female reproductive system of the Lemurs recalls that of the Anthropoids. It is interesting to note that in *Lemur Propithecus* and *Indris* only one young is produced at a birth; whether this number of young is typical of the whole suborder

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[26] Wallace, Dr. A. Russel. The Permanence of the Great Oceanic Basins. Nat. Science, Vol. I, No. 6, August, 1892, p. 418–426; and "Island Life," second ed., 1892.

[27] Seward, A. C. The Glossopteris Flora. Science Progress, New Series, Vol. I, No. 2, January, 1897, p. 178–201. (This paper gives the Bibliography relating to the Anarctic continent.)